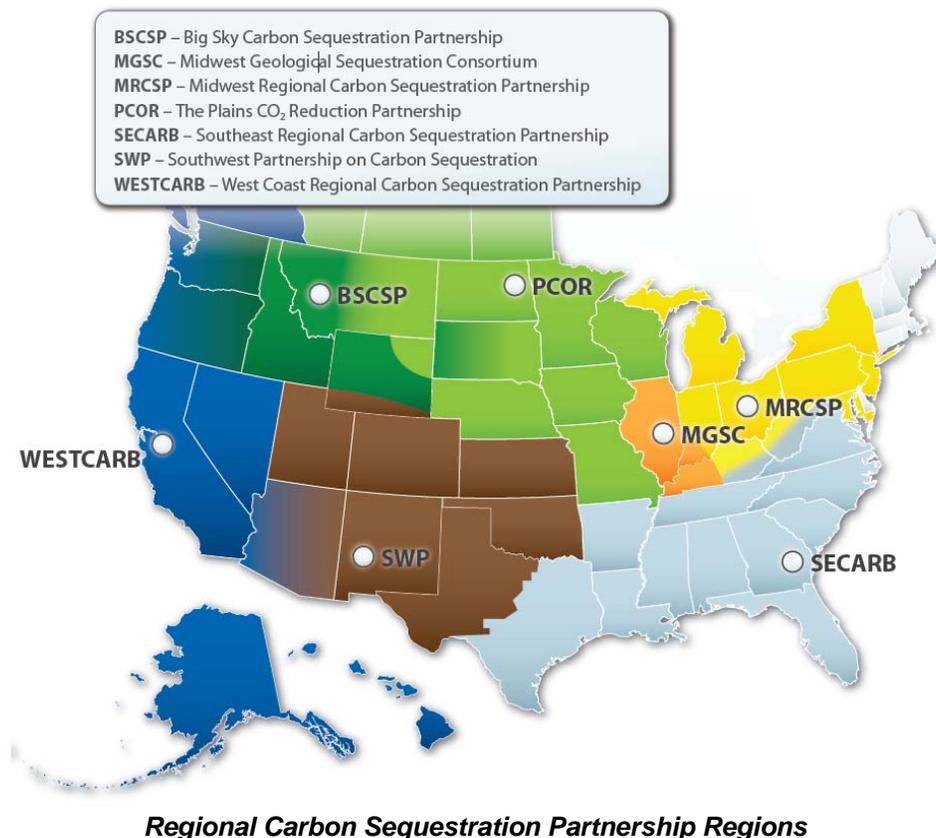


Regional Carbon Sequestration Partnerships

DOE determined early in the program's development that addressing CO₂ mitigation from power and industrial sources regionally would be the most effective way to address differences in geology, climate, population density, oil and gas infrastructure, human capital, and socioeconomic development throughout the United States. To support the development of regional infrastructure for CCS, this Technology Area consists of several efforts, including:

- National efforts to characterize storage formations and reduce uncertainty associated with storage resource estimates.
- Implement small- and large-scale CO₂ field tests in different geologic formation classes representing various depositional environments.
- Development of geologic storage Best Practices Manuals to communicate lessons learned from field tests to industry, regulators, and the public.
- Supporting the development of human capital, stakeholder networking, regulatory policy development, carbon mitigation plans, and public outreach and education throughout the United States.

DOE has created a network of seven Regional Carbon Sequestration Partnerships (RCSPs) to develop the technology, infrastructure, and regulations needed to implement large-scale CO₂ storage in different regions and geologic formations. The RCSP Technology Area research effort is carrying out regional characterization and small- and large-scale field tests to demonstrate that different types of geologic storage reservoirs, distributed over different geographic regions, have the capability to permanently store CO₂ and provide the basis for commercial-scale CO₂ tests. RCSP field tests involve integrated system testing and validation of geologic storage, simulation and risk assessment, and MVA technologies in different depositional environments



Regional Carbon Sequestration Partnerships

The RCSP Initiative is being implemented in three phases:

- Characterization Phase (2003–2005): Initial characterization of each region's potential to store CO₂ in various geologic formations.
- Validation Phase (2005–2013): Validation of the most promising regional storage opportunities through a series of small-scale field tests.
- Development Phase (2008–2020+): Implementation of large-scale field testing involving injection of at least 1 million metric tons of CO₂ per project to confirm that CO₂ injection and storage can be achieved safely, permanently, and economically.

The RCSP effort addresses multiple technical challenges associated with CO₂ injection and storage. Work is being performed to understand how the chemical interactions of fluids (water, oil, and gas) and reservoir rock, geomechanical properties, compartmentalization, heterogeneity, seismicity, and reservoir architecture impact CO₂ storage and other impurities that might be present in the injection stream. Eleven classes of geologic storage formations (deltaic, shelf clastic, shelf carbonate, strandplain, reef, fluvial deltaic, eolian, fluvial and alluvial, turbidite, coal, and basalt) and two classes of seals (shale and evaporites) are currently being investigated. The reason for performing studies for each of these classes is to determine:

- The effectiveness of CO₂ injection and storage operations.
- Validate geologic storage, simulation and risk assessment, and MVA technologies.

Validation Phase Field Projects

Small-scale CO₂ injection tests performed through the RCSP Validation Phase in different types of geologic formations and depositional environments are focused on contributing to the understanding of CO₂ behavior and migration in the full range of depositional environments/classes of storage formations. These tests are also aimed specifically at understanding CO₂ injectivity; validating CO₂ storage resource potential through both regional and project-specific characterization efforts; ensuring that CO₂ can be injected and stored safely, permanently, and economically; as well as validating and field testing CCS technologies through all stages leading to commercialization.

The Validation Phase has accounted for 20 total field projects. To date, eight RCSP Validation Phase projects have completed CO₂ injection into depleted oil and gas fields; five projects have completed injection into saline formations; and five projects have completed injection into unmineable coal seams. These projects have helped to facilitate future CCS opportunities in North American and provided a foundation for implementation of the large-scale field tests in the Development Phase.

Regional Carbon Sequestration Partnerships



RCSP Validation Phase CO₂ Injection Project Locations

Small-Scale CO₂ Injection Project Details

	Project Name	RCSP/State	Project Type	Injection Formation(s) (Reservoir)	Planned CO ₂ Injected (metric tons total) April 2012
1	Wallula Basalt Pilot Study	Big Sky	Basalt	Interflow zones, Grande Ronde Basalt	1,000*
2	Loudon Single Well Huff N Puff Project	MGSC	HNP	Cypress & Mississippi Weiler SS	39
3	Mumford Hills Project	MGSC	EOR	Clore Sandstone	6,560
4	Sugar Creek Project	MGSC	EOR	Jackson Sandstone	6,300
5**	Illinois Basin – Mt. Simon Sandstone Project	MGSC	Saline	Mt. Simon Sandstone	180,000
6	Tanquary Well Project	MGSC	ECBM	Springfield Coal	91
7	Appalachian Basin Geologic Test at R.E. Burger Power Plant: Fegenco Well	MRCSP	Saline	Clinton SS / Salina Fm / Oriskany SS	50
8	Duke Energy - East Bend Well Site	MRCSP	Saline	Mt Simon	1,000
9	Michigan Basin Geologic Test	MRCSP	Saline	Bass Islands Dolomite	60,000
10	Zama Acid Gas EOR, CO ₂ Storage, and Monitoring Project	PCOR	EOR	Middle Devonian Keg River Formation	80,000 acid gas

Regional Carbon Sequestration Partnerships

11	NW McGregor EOR HNP Project	PCOR	EOR / HNP	Mission Canyon Limestone	400
12	Lignite CCS Project	PCOR	ECBM	Lignite Seams in Ft. Union Formation	80
13	Gulf Coast Stacked Storage Project	SECARB	EOR	Tuscaloosa Formation	627,744
14	Plant Daniel Project	SECARB	Saline	Massive Sand, Lower Tuscaloosa	2,740
15	Central Appalachian Basin Coal Test	SECARB	ECBM	Pocahontas & Lee Formation	907
16	Black Warrior Project	SECARB	ECBM	Pottsville Formation (coal zones)	252
17	Aneth EOR Sequestration Test	SWP	EOR	Desert Creek & Ismay Formation	630,000
18	SACROC CO ₂ Injection Project	SWP	EOR	Horseshoe Atoll & Pennsylvanian Reef/Bank Play	86,000
19	Pump Canyon CO ₂ -ECBM/Sequestration Demonstration	SWP	ECBM	Fruitland Coal Formation	16,700
20	Arizona Utilities CO ₂ Storage Pilot	WESTCARB	Saline	Martin & Naco Formations	None
-	Northern California Geologic Characterization	WESTCARB	Geologic Characterization	Domengine, Mokelumne River, H&T/Starkey SS	None

*Injection Planned

**Project moved to Large-Scale Development Phase

Development Phase Field Projects

The RCSP's large-scale field projects build on the results of the characterization activities and small-scale field projects. These large-scale projects involve the injection of 1 million metric tons or more of CO₂ into regionally significant geologic formations of various depositional environments. These large-volume field projects are designed to demonstrate the potential for CO₂ storage sites to store regional CO₂ emissions safely, permanently, and economically for hundreds of years. Carbon dioxide sources include natural deposits, ethanol facilities, natural gas processing plants, and capture from power plants. Large-scale projects will contribute to a better understanding of all the aspects of commercial-scale CCS projects, including regulatory, liability, and ownership issues associated with these projects. Large-scale projects will also provide a firm foundation for commercialization of large-scale CCS.

The storage types and formations being tested are considered regionally significant and are expected to have the potential to store hundreds of years of CO₂ from stationary source emissions. As of August 2013, approximately 4 million metric tons of CO₂ have been stored in various geologic formations via the large-scale field tests being implemented by the RCSPs.

In the near term, large-scale projects will support and validate the industry's ability to ensure storage permanence in reservoirs in different depositional environments supporting first mover projects. Specifically, large-scale field tests will continue to address practical issues, such as sustainable injectivity, well design for integrity, storage resource utilization (utilization of pore space and oil and gas recovery), and reservoir behavior—with respect to prolonged injection. Complete assessments of these issues are necessary to validate and improve model predictions concerning the behavior of injected CO₂ at scale, establish the engineering and scientific processes for successfully implementing and validating safe long-term storage, and achieve cost-effective integration with power plants and other large industrial emission sources for carbon capture.

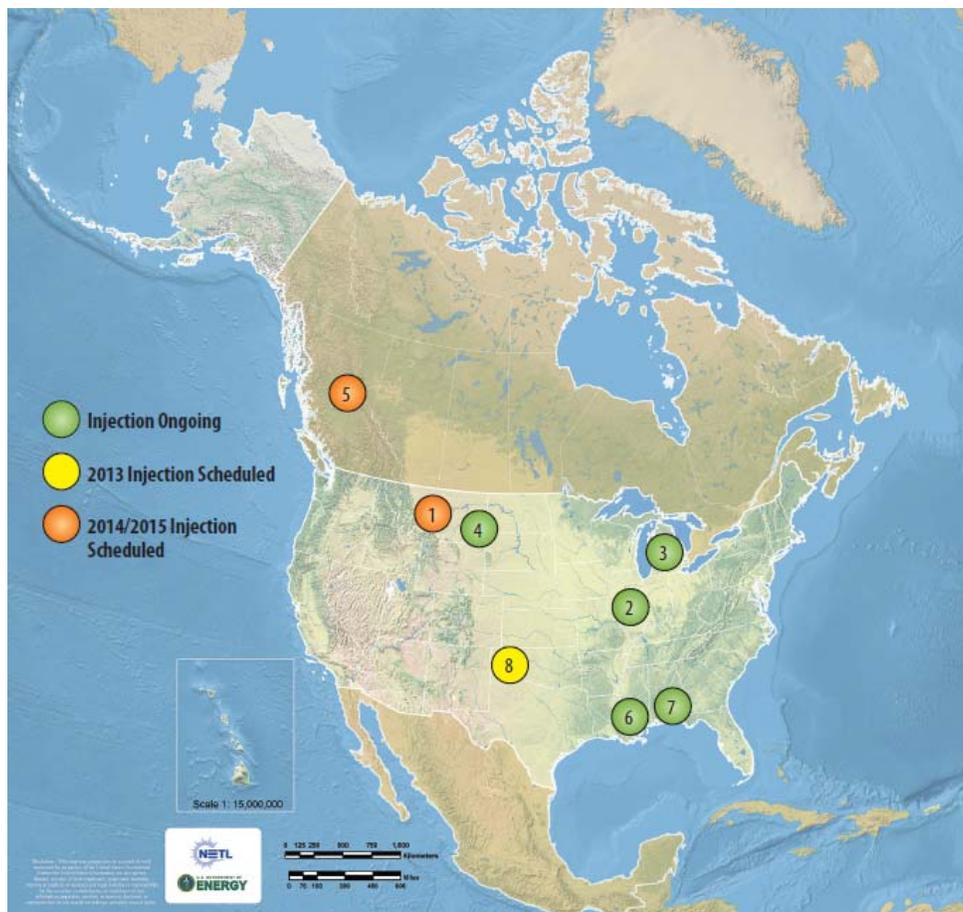
The large-scale field tests are implemented in three stages and typically require 10 years to implement. These three stages include the site characterization, injection operations, and post-injection monitoring. In order to

Regional Carbon Sequestration Partnerships

validate that CCS can be conducted at commercial scale, a number of key research pathways are being pursued by each of the large-scale projects:

- Prove adequate injectivity and available capacity at pre-commercial scale.
- Prove storage permanence by validating that CO₂ will be retained in the subsurface, and that projects do not adversely impact underground sources of drinking water and/or cause CO₂ to be released to the atmosphere, while also developing technologies and protocols to quantify potential releases.
- Determine the areal extent of the CO₂ plume/pressure front and potential release pathways by monitoring the areal and vertical migration of the CO₂ during and after project completion, and develop methodologies to determine the presence/absence of release pathways.
- Develop risk assessment strategies by identifying risk parameters, probability and potential impact of occurrences, and mitigation strategies for each field site.
- Engage in the development of an effective regulatory and legal framework for the safe injection and long-term geologic CO₂ storage in the regions where the projects are developed.

Results obtained from these efforts will provide the foundation for validating that CCS technologies can be commercially deployed and monitored throughout the United States. These and future large-scale projects will be necessary to validate storage projects integrated with carbon capture technologies from various CO₂ sources and geologic storage in all storage formation types in multiple basins throughout the United States.



Large-Scale CO₂ Injection Projects Map

Regional Carbon Sequestration Partnerships

Large-Scale CO₂ Injection Project Detail

	RCSP	Geologic Province	Target Injection Volume (metric tons)
1	Big Sky	Nugget Sandstone	1,000,000
2	MGSC	Illinois Basin – Mt. Simon Sandstone	1,000,000
3	MRCSP	Michigan Basin – Niagaran Reef	1,000,000
4	PCOR	Powder River Basin – Bell Creek Field	1,500,000
5		Horn River Basin – Carbonates	2,000,000
6	SECARB	Gulf Coast – Cranfield Field – Tuscaloosa Formation	2,902,000
7		Gulf Coast – Paluxy Formation	450,000
8	SWP	Regional CCUS Opportunity	1,000,000
	WESTCARB	Regional Characterization	